

EXHIBIT I

**THE UNITED STATES DISTRICT COURT
FOR THE EASTERN DISTRICT OF TEXAS
MARSHALL DIVISION**

FRACTUS, S.A., Plaintiff, v.	
AT&T MOBILITY LLC, Defendant, and COMMSCOPE TECHNOLOGIES LLC and CELLMAX TECHNOLOGIES AB, Intervenor-Defendants.	Case No. 2:18-cv-00135-JRG LEAD CASE
SPRINT COMMUNICATIONS COMPANY, L.P., ET AL., Defendants, and COMMSCOPE TECHNOLOGIES LLC and CELLMAX TECHNOLOGIES AB, Intervenor-Defendants.	Case No. 2:18-cv-00136-JRG
T-MOBILE US, INC., ET AL., Defendants, and COMMSCOPE TECHNOLOGIES LLC and CELLMAX TECHNOLOGIES AB, Intervenor-Defendants.	Case No. 2:18-cv-00137-JRG
CELLCO PARTNERSHIP d/b/a VERIZON WIRELESS, Defendant,	Case No. 2:18-cv-00138-JRG

and

COMMSCOPE TECHNOLOGIES LLC,

Intervenor-Defendant.

DECLARATION OF PETER C. KARLSSON

1. My name is Peter C. Karlsson. I am over 18 years of age and of sound mind and capable of making this affidavit, and personally acquainted with the facts herein stated. If called as a witness, I could and would testify under oath to the facts stated in this declaration.

2. I have worked in the cellular telecommunications industry for over twenty years. I hold a Doctor of Philosophy degree (Ph.D.) in radio communications from Lunds tekniska högskola. I am currently the director of the Sony Research and Standardization labs at Sony Mobile Communications in Lund, Sweden.

3. In the year 1998, I worked for Telia Research AB in Malmö, Sweden. My email address at Telia at the time was peter.c.karlsson@telia.se. During that timeframe, on information and belief, Telia was the largest provider of telecommunications services in Sweden and also provided telecommunications services to other Nordic countries including Denmark, Norway and Finland.

4. As an active member of the telecommunications industry in Sweden for over two decades, I am familiar with the Nordic Radio Society (“NRS”). Among other things, NRS organized an event called the Nordic Radio Symposium every three years for many years. These symposiums were open to anyone who paid the admission fee (subject to availability). Over the years, I attended several of these NRS symposiums including one held on October 19-22, 1998 at the Grand Hotel in Saltsjöbaden, Sweden (hereafter “NRS 1998”).

5. NRS 1998 was attended by members of the leading Nordic radio telecommunications companies at the time including Telia, Ericsson Radio, and Allgon System. In addition, researchers in radio telecommunications from major Nordic universities including Lunds and KTH participated in the symposium.

6. Numerous technical papers were presented at the NRS 1998 symposium including one of that I co-authored with my colleague from Telia Research, Christian Begljung, entitled “Propagation Characteristics for Broadband Radio Access Networks in the 5 GHz Band.” There were no confidentiality restrictions on the dissemination of the information presented at the symposium. For example, attendees did not have to sign a confidentiality or non-disclosure agreement to attend. Indeed, one of main purposes of the NRS 1998 symposium was to facilitate sharing and dissemination of technical information among and between researchers and engineers in the telecommunication industry and academia. Attendees also were permitted to take notes during the presentations.

7. At the start of the NRS 1998 symposium each attendee including myself was presented with a bound copy of the symposium proceedings. The proceedings included printed copies of papers presented at the symposium including a copy of my paper. I still possess the bound copy of the proceedings I received at the NRS 1998 symposium on or before October 22, 1998. The title of the symposium proceedings is “Broadband Radio Access,” spans over 200 pages, and includes a paper on pages 69-72 entitled “Dual Band Base Station Antenna Systems,” by Björn Lindmark, Mikael Ahlberg, Jesper Simons, Stefan Jonsson, Dan Karlsson, and Claes Beckman of Allgon System. Attached hereto as Exhibit A is a true and correct copy of that paper (along with the cover pages and table of contents) from the bound copy of the symposium proceedings I received at the NRS 1998 symposium on or before October 22, 1998.

8. I declare that all statements made herein on my own knowledge are true and that all statements made on information and belief are believed to be true, and further, that these statements were made with the knowledge that willfully false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code.

Executed this 7 day of January 2019, in Lund, Sweden.

By:


Peter C. Karlsson

EXHIBIT A



Broadband Radio Access

Conference Proceedings

Nordic Radio Symposium 1998

Saltsjöbaden, Sweden

19 - 22 October 1998

SNRV- THE SWEDISH NATIONAL COMMITTEE OF URSI

SNRV was founded in 1931 as the Swedish National Committee of the International Union of Radio Science (URSI). There are corresponding committees in the other Nordic countries.

SNRV has 22 members and in addition about 125 co-opted members. The objective of SNRV is to promote the scientific research and technical development of radio in Sweden. SNRV is also responsible for the representation of Sweden in URSI.

The SNRV members work in sections as the URSI Commissions. Each section chairman is also the official Swedish representative of the corresponding URSI Commission.

SNRV and URSI are also in charge of arranging national and international conferences in order to spread scientific results and to make the radio scientific field a subject of debate. NRS 98, as the previous four Nordic Radio Symposia, are steps in this progress.

Contents

page

01	DECT, Digital Enhanced Cordless Telecommunication	
	<i>Dag Åkerberg</i>	
	Ericsson Radio Systems AB	1
02	Propagation Characteristics for Broadband Radio Access Networks in the 5 GHz Band	
	<i>Peter Karlsson, Christian Bergljung</i>	
	Telia Research AB	17
03	Wideband Channel Measurements at 18 GHz in the City of Stockholm	
	<i>Mikael Larsson</i>	
	Telia Research AB	25
04	Propagation at 40 GHz in the Context of Providing Interactive Broadband Services: First Measured Results of Effects from Precipitation and Vegetation	
	<i>T. Tjelta, A. Paulsen, L. Pedersen, O. Alsos, P.I. Jensen</i>	
	Telenor Research and Development	33
05	Radio Propagation in Curved Road Tunnels	
	<i>Martin Nilsson, Jesper Slettenmark, Claes Beckman</i>	
	Allgon System AB	41
06	Polarization Diversity in DS-CDMA Systems	
	<i>Francesco Sapienza</i>	
	Allgon System AB	47
07	The Effect of Far-Field Characteristics on the Diversity Reception of a Dual Polarized Antenna	
	<i>Björn Lindmark, Martin Nilsson</i>	
	Allgon System AB	53
08	Antenna Diversity for Mobile Telephones	
	<i>Christian Braun</i>	
	Allgon Mobile Communications AB	61
09	Dual Band Base Station Antenna Systems	
	<i>B. Lindmark, M. Ahlberg, J. Simons, S. Jonsson, D. Karlsson, C. Beckman</i>	
	Allgon System AB	69
10	An Extension of a Heuristic UTD Diffraction Coefficient for Nonperfectly Conducting Wedges	
	<i>Peter D. Holm</i>	
	Defence Research Establishment	75
11	Wideband Radio Access	
	<i>Andrew Perkis, Knut Grythe</i>	
	NTNU, SINTEF	79

- iv -

		page
12	PCC - A Strategic Research Program in Personal Computing and Communication <i>Bengt Arne Molin</i> Dept. of Appl.Electronics, Lund University	87
13	Cellular Radio Access for Broadband Services (CRABS): An Overview of the ACTS Project AC215 <i>Agne Nordbotten</i> Telenor Research and Development	95
14	WCDMA - The Radio Interface for UMTS/IMT2000 <i>J. Bergström, M. Gustafsson, P. Narvinger, H. Olofsson</i> Ericsson Radio Systems AB	103
15	An ATM Based Wireless Broadband Access System <i>Aldo Bolle, Örjan Eriksson</i> Ericsson Microwave Systems AB	111
16	EDGE - Enhanced Data Rates for GSM and IS-136 Evolution <i>A. Furuskär, M. Höök, C. Johansson, S. Jäverbring, K Zangi</i> Ericsson Radio Systems AB	119
17	Power Control for Coded Frequency Hopping Cellular Systems <i>Kai-Erik Sunell, Jens Zander</i> Radio Communication Systems, KTH	127
18	Power Control in Cellular Radio Systems with Multicast Traffic <i>Carl-Gustav Löf</i> Radio Communication Systems Lab., KTH	133
19	Technical Trial with Wireless ATM Access at 28 GHz <i>Peter Karlsson, Niclas Löwendahl, Patrik Walter</i> Telia Research AB	141
20	A 40 GHz Broadband Access Trial at Kjeller, Norway <i>T. Tjelta, A. Nordbotten, R.S. Ling, H. Loktu, P.S. Hansen, S. Nilsen, O. Grøndalen</i> Telenor Research and Development	149
21	Single Frequency Network Planning for DAB/DVB with Individual Data Services <i>Agnes Ligeti</i> Radio Communication Systems, KTH	157
22	Adaptive Coding and Signal Proc. using a Conventional Radio Com. Link for the purpose of Characterizing Objects and Environmental Phenomena <i>Dag T Gjessing</i> Triad AS	165

- iv -

	page
12 PCC - A Strategic Research Program in Personal Computing and Communication <i>Bengt Arne Molin</i> Dept. of Appl. Electronics, Lund University	87
13 Cellular Radio Access for Broadband Services (CRABS): An Overview of the ACTS Project AC215 <i>Agne Nordbotten</i> Telenor Research and Development	95
14 WCDMA - The Radio Interface for UMTS/IMT2000 <i>J. Bergström, M. Gustafsson, P. Narvinger, H. Olofsson</i> Ericsson Radio Systems AB	103
15 An ATM Based Wireless Broadband Access System <i>Aldo Bolle, Örjan Eriksson</i> Ericsson Microwave Systems AB	111
16 EDGE - Enhanced Data Rates for GSM and IS-136 Evolution <i>A. Furuskär, M. Höök, C. Johansson, S. Jäverbring, K Zangi</i> Ericsson Radio Systems AB	119
17 Power Control for Coded Frequency Hopping Cellular Systems <i>Kai-Erik Sunell, Jens Zander</i> Radio Communication Systems, KTH	127
18 Power Control in Cellular Radio Systems with Multicast Traffic <i>Carl-Gustav Löf</i> Radio Communication Systems Lab., KTH	133
19 Technical Trial with Wireless ATM Access at 28 GHz <i>Peter Karlsson, Niclas Löwendahl, Patrik Walter</i> Telia Research AB	141
20 A 40 GHz Broadband Access Trial at Kjeller, Norway <i>T. Tjelta, A. Nordbotten, R.S. Ling, H. Loktu, P.S. Hansen, S. Nilsen, O. Grøndalen</i> Telenor Research and Development	149
21 Single Frequency Network Planning for DAB/DVB with Individual Data Services <i>Agnes Ligeti</i> Radio Communication Systems, KTH	157
22 Adaptive Coding and Signal Proc. using a Conventional Radio Com. Link for the purpose of Characterizing Objects and Environmental Phenomena <i>Dag T Gjessing</i> Triad AS	165

- v -

	page
23 Word Length Optimization of an 8k Points FFT <i>Stefan Johansson, Shousheng He, Peter Nilsson</i> Dept. of Appl. Electronics, Lund University	175
24 Quantitative Distortion Assessment with SNR Estimation in OFDM System Simulation <i>Shousheng He, Mats Torkelson</i> Dept. of Appl. Electronics, Lund University	179
25 Pulse Shaping in OFDM Schemes <i>Slimane Ben Slimane</i> Radio Communication Systems, KTH	187
26 Assessing Interleaver Suitability for Turbo Codes <i>Johan Hokfelt, Ove Edfors, Torleif Maseng</i> Dept. of Appl. Electronics, Lund University	195
27 Convolutional Coding and ARQ Schemes for Wireless Communication <i>S. Falahati, P. Frenger, P. Orten, T. Ottoson, A. Svensson</i> Dept. of Signals and Systems, Chalmers UT	203
28 Considerations regarding the number of RAKE fingers required in CDMA RAKE-receivers <i>Andres A. Glazunov</i> Ericsson Radio Systems AB	211
29 Detectors Based on Non-Decision Directed Interference Cancellation in a Hardware Implementation Perspective <i>T. Olsson, C.M. Jönsson, V. Öwall, P. Nilsson</i> Dept. of Appl. Electronics, Lund University	219
30 2 GHz Silicon Bipolar LNA <i>Jakob Thorell</i> Ericsson Radio Systems AB	227
31 1.8 GHz Low Voltage VCO in Silicon Bipolar Technology <i>Fredrik Jonsson</i> Dept. of Electronics, KTH	231

Dual Band Base Station Antenna Systems

Björn Lindmark, Mikael Ahlberg, Jesper Simons, Stefan Jonsson, Dan Karlsson, and Claes Beckman

Abstract— An analysis of the possibilities of using dual band antennas in cellular radio is presented. Results from simultaneous measurements at 900 MHz and 1800 MHz are presented and analyzed. Based on the measured results, a dual polarized, dual band base station antenna has been designed. Such an antenna provides the opportunity to replace a 4 antenna space diversity installation with a single antenna, thereby reducing costs and tower space.

I. INTRODUCTION

The demand for antennas for mobile wireless applications has increased dramatically over the last 10 years. Today we have a number of land and satellite based systems for wireless communications using a wide range of frequency bands. Not only do we see an increase in the number of subscribers in the different systems but also a demand for dual band equipment capable of handling two or more systems. Due to the capacity problems encountered today in the AMPS (824-894 MHz) and GSM (880-960 MHz) systems in Europe and North America, many operators have acquired a license for the 1900 MHz PCS or 1800 MHz DCS bands respectively.

Since a major problem during the deployment of a cellular radio network is to find suitable sites for the base stations, one can expect these operators to use their existing sites for the new base station wherever possible. In an urban or sub-urban environment, the cost of installation of feeder cables and antennas as well as the overall need to reduce the number of antennas then makes a dual band antenna attractive. One way of implementing this would be to replace an existing GSM or AMPS antenna with a dual band GSM/DCS or AMPS/PCS antenna. Such dual band operation is perhaps more useful for the GSM/DCS operators where the protocols of the two systems are close to identical [1], and we will therefore restrict the discussion to this case.

A concern regarding dual band wireless systems is the different propagation in the two bands. The antenna gain of a hand-held mobile terminal is practically 0 dB in both bands due to its omnidirectional pattern, and the gain of the base station antenna is at best 3 dB higher in the upper band if the same vertical length antenna is used in both bands with the same azimuth coverage. This means that even in a free-space scenario, we can expect 3 dB higher path loss in the 1800 MHz band than in the 900 MHz band. However, the difference in path loss for the two bands in a real world radio environment is found to be rather in the order of 10 dB [2], both in simulations and measurements. Depending on how a dual band system is set up this differ-

ence may or may not be crucial. If one seeks to co-site the two bands and use identical cellplanning, the smaller this difference is, the higher capacity is provided by the new 1800 MHz channels. As long as the major part of the cell area is covered by the new 1800 MHz channels, traffic may be moved to these channels thus decreasing the load on the 900 MHz channels. It may also be possible to substantially reduce the signaling in the network by allocating the Broad Cast CHannels (BCCH) in only one band. On the other hand, if additional capacity is needed throughout an area, the need for similar coverage is higher.

The use of diversity reception is essential in mobile radio to combat fading and we have seen an increased interest in the use of polarization diversity [3-5] at the base station instead of the traditional space diversity. This reduces the bulky space diversity installation to a single antenna installation. Since the motivation for a dual band antenna is primarily to reduce the number of antennas installed, the full potential of a dual band antenna system calls for dual polarization operation as well. A dual polarized, dual band antenna makes it possible reduce a four antenna installation two a single antenna installation and is therefore very attractive for the operator. If two band-separating filters are placed at the base station, it is also possible to use only two feeders instead of four. This means reduced cost, wind load, weight and installation time.

In this paper we first present simultaneous measurements of the path loss at 900 MHz and 1800 MHz. We are primarily interested in the statistical properties of the propagation at different distance since this is the main property related to the design of a dual band antenna, in terms of both vertical and horizontal pattern. Therefore we analyze the measured data statistically as a function of the distance between the base station and the mobile rather than in terms of point-to-point propagation.

We then present a dual band, dual polarized antenna designed for use in an urban or sub-urban environment. Based on the conclusions from the measurements mentioned above, the antenna is designed for maximum gain in both bands.

II. DUAL BAND PROPAGATION MEASUREMENTS

We performed a set of down-link measurements in a sub-urban area in Täby which is located north-east of Stockholm, Sweden. The base station antennas were placed on an 8 m tower on top of a 30 m high-rise residential building. The building is located on a hill which places the antennas some 50 m above the surrounding terrain. Figs. 1-2 shows the view north and east from the base station site. The antennas were directed at a compass bearing of 340° and Fig. 3 shows a map of the measurement area. This sub-urban area is characterized by mostly residential houses,

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- 70 -



Fig. 1. View north over most of the measurement area in Täby, Sweden.

some higher apartment buildings next to the Täby shopping mall and fairly low rolling hills. There is a significant amount of vegetation present, mostly in the form of trees. The measurements were performed in June so we have maximum blockage by the foliage and therefore only line-of-sight in a few locations in the area.

On the tower shown in Fig. 2, we mounted two vertically polarized base station antennas, one for each frequency band. Both antennas had a horizontal half-power beamwidth of 65° and a vertical pattern with a half-power beamwidth of 14° and 15° , respectively, and an electrical down-tilt of 6° . The gain of the antennas were 15.5 dB and 15 dB respectively. Given the base station antenna height of 50 m above the surrounding terrain this places the maximum of the vertical radiation pattern at a distance of 480 m. Furthermore the lower 3 dB point is at 220 m and the upper is above the horizon. The maximum distance in these measurements is 3700 m corresponding to an elevation of -0.8° . Thus the complete measurement area falls within the main beam in elevation and there is no concern that we measure path loss to a point which is in a null in the pattern.

The base transceiver station (BTS) transmitted a power of 12 W in GSM and 18 W in DCS. On the receive end there were two vertically polarized roof antennas mounted on a car. The data was collected using two TEMS units [6], each connected to a GPS (Global Positioning System) unit. One TEMS unit was used for GSM 900 MHz and one for DCS 1800 MHz. The TEMS units were calibrated at the frequencies of interest over the range from -35 dBm to -100 dBm. It turned out that the 1800 MHz TEMS showed -4 dB relative the true value in all cases and this error was accounted for in the following data analysis. Each TEMS unit was locked onto a TRX-channel and measured the received power 2-3 times per second. The car traveled practically every street in the measurement area as indicated by the plot of the individual measurement points in Fig. 4. The measurement locations are actually determined by the possibility to trace a call at 1800 MHz, and the route in



Fig. 2. View west over the measurement area also showing tenna site and two of the authors.



Fig. 3. Map over the measurement area. The BTS is 'x' close to the lower edge of the map.

- 70 -

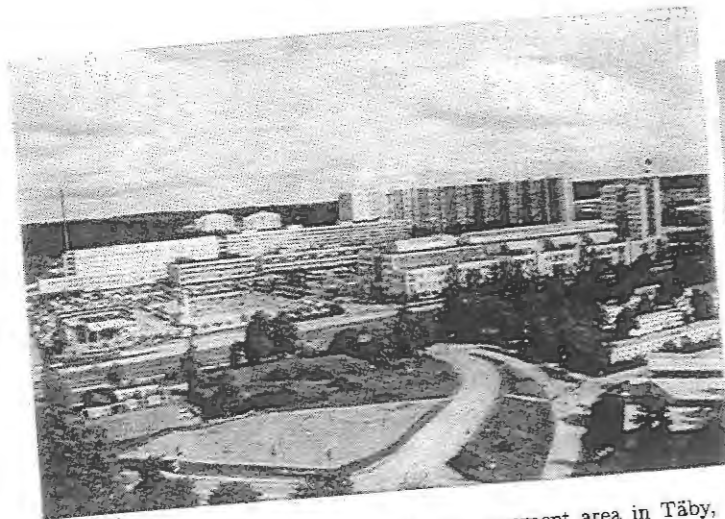


Fig. 1. View north over most of the measurement area in Täby, Sweden.

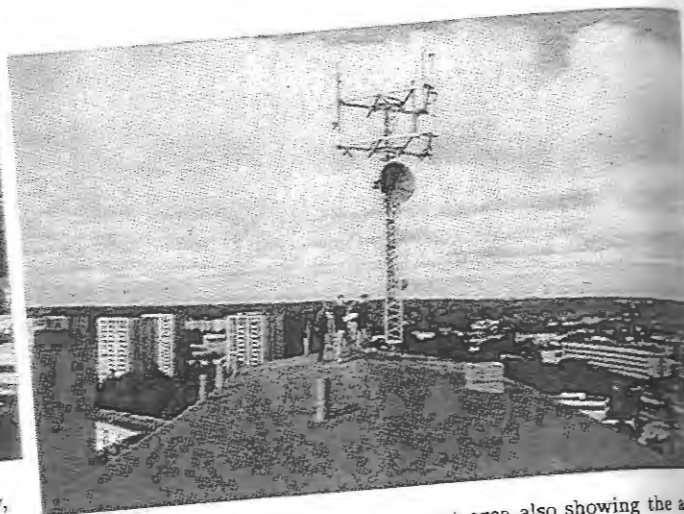


Fig. 2. View west over the measurement area also showing the antenna site and two of the authors.

some higher apartment buildings next to the Täby shopping mall and fairly low rolling hills. There is a significant amount of vegetation present, mostly in the form of trees. The measurements were performed in June so we have maximum blockage by the foliage and therefore only line-of-sight in a few locations in the area.

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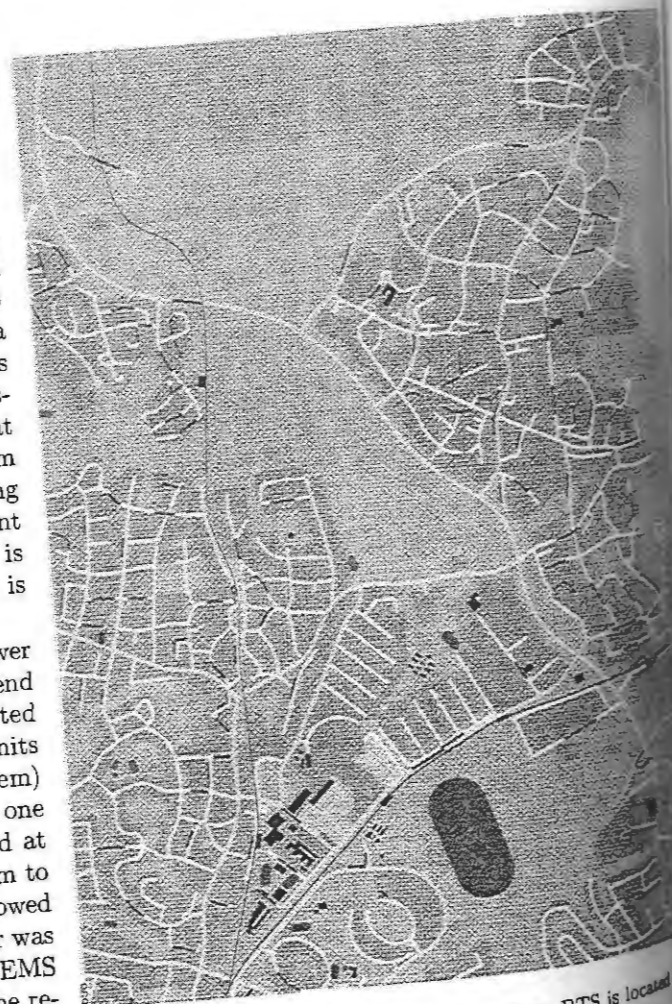


Fig. 3. Map over the measurement area. The BTS is located 'x' close to the lower edge of the map.

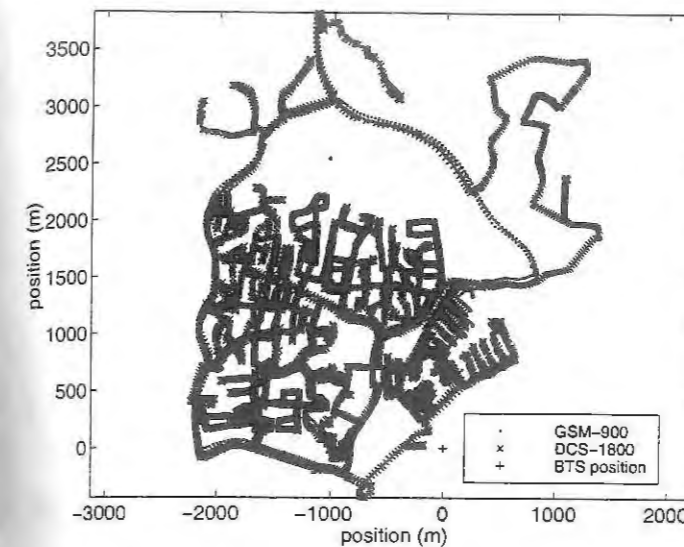


Fig. 4. Location of the individual measurement points.

Fig. 4 therefore shows the effective cell size in this band. As we can see from a close look in Fig. 4, another source of error was the two GPS units. Although the constant biased error was accounted for by reading the instrument at a known location, the position found from the instruments still differs by up to 50 m. This is true also for measurements at different time on the same street with the same instrument. However, for the purposes of the path loss vs. distance analysis in this paper the error is still negligible.

A total of 38 725 GSM-900 and 35 446 DCS-1800 data were collected. The azimuth angle from the base station antenna to each point was calculated so that the received power could be adjusted to account for the known azimuth pattern of the antenna. In order to facilitate the further analysis of the data we grouped the data for each 0.075 of \log_{10} of the distance to the base station. This produced 18 and 19 data groups respectively. We then compensated for a feeder loss of 1.3 dB at 900 MHz and 1.8 dB at 1800 MHz. Finally we calculated the path loss as $P_{RX} - P_{TX}$ and for each data group the mean and the standard deviation is shown in Fig. 5. The 1800 MHz values have been shifted by +0.5 dB to relate the results to same gain as the 900 MHz values (15 dB). Note that due to extreme line-of-sight conditions close to the BTS the received power actually increased with distance the first few hundred meters; these data are not shown in Fig. 5. The standard deviation of the data groups is acceptable and ranges from 2 dB to 11 dB for GSM-900 and 1.8 dB to 11.5 dB for DCS-1800. For most data groups the standard deviation is close to the 4 dB mentioned in [7].

A linear fit to all the data yields a increase in path loss of 48 dB/dec for GSM and 55 dB/dec for DCS. This loss is considerably higher than the 30-40 dB/dec found for sub-urban and urban environments in [7, 8]. A possible cause for the high path loss is the presence of trees and foliage throughout the measurement area as seen in Figs. 1, 2. In [7] it is stated that foliage could provide a

- 71 -

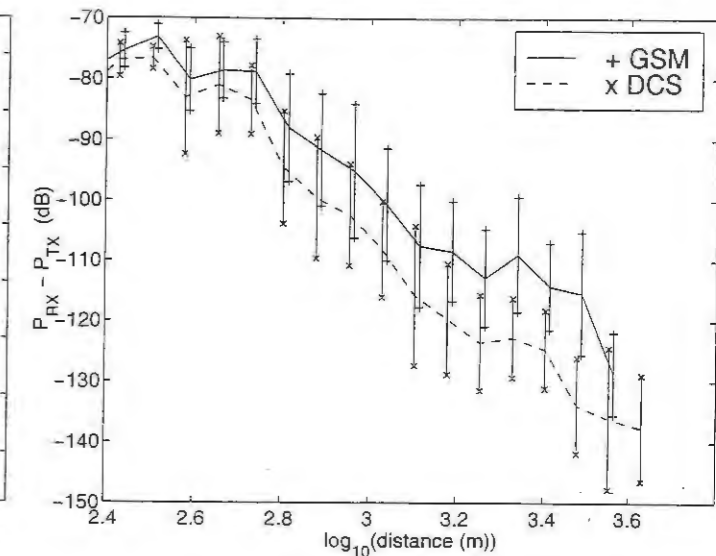


Fig. 5. Average path loss $P_{RX} - P_{TX}$ at GSM 900 MHz and DCS 1800 MHz as a function of distance from the base station. The average \pm one standard deviation is shown for each data group. The different radiated power due to the horizontal radiation pattern of the base station antennas has been compensated for and the values assume a 15 dB base station antenna gain.

total path loss of up to 60 dB/dec at 800 MHz. If we also consider a foliage loss depending on the frequency as f^4 [7] we have an explanation for the larger attenuation at 1800 MHz compared to 900 MHz. Alternatively, we can use the numerical analysis in [9] where the tree-specific attenuation for vertically polarized waves is calculated to be 0.7 dB/m at 900 MHz and 1.4 dB/m at 1800 MHz. Since the propagation distance through trees increases with distance due to more grazing incidence towards the mobile, this explains why the difference between the average path loss for 1800 MHz and 900 MHz increase from 3 dB to 12 dB over a decade in Fig. 5.

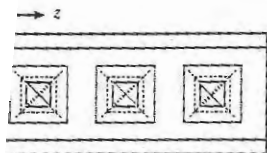
III. A DUAL POLARIZED DUAL BAND PANEL ANTENNA

As seen in the previous section, the path loss in a sub-urban environment can be 10-15 dB higher at 1800 MHz than at 900 MHz. In some instances we might therefore need all the extra antenna gain possible at 1800 MHz compared to 900 MHz. We have developed a dual polarized, dual band panel antenna for the 872-960 MHz and 1710-1880 MHz frequency bands. The polarization is $\pm 45^\circ$ linear which is desirable in diversity reception since it provides equal mean power on the two branches. The antenna is a sector antenna for a cellular network and the desired beamwidth is 72° with respect to -3 dB total power.

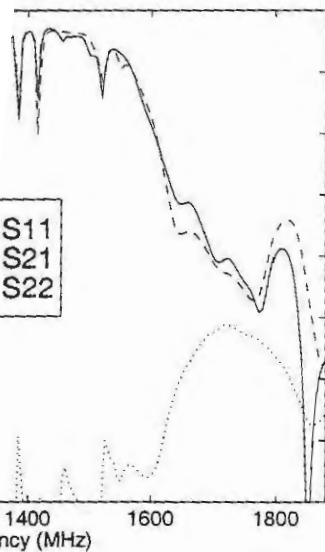
A. Antenna Design

The antenna element is an aperture coupled stacked patch with the symmetry needed for good dual polarization operation as described in [10] but with the apertures aligned $\pm 45^\circ$ to the vertical axis. The elements thus provide slant $\pm 45^\circ$ linear polarization. The antenna consists of

- 72 -



showing the 7 dual polarized



the antenna array.

near array. There is no dis-
the centerline which allows
urns, low cross-polarization,
two channels. Fig. 6 shows
The dimensions are 1200
s consists of three stacked
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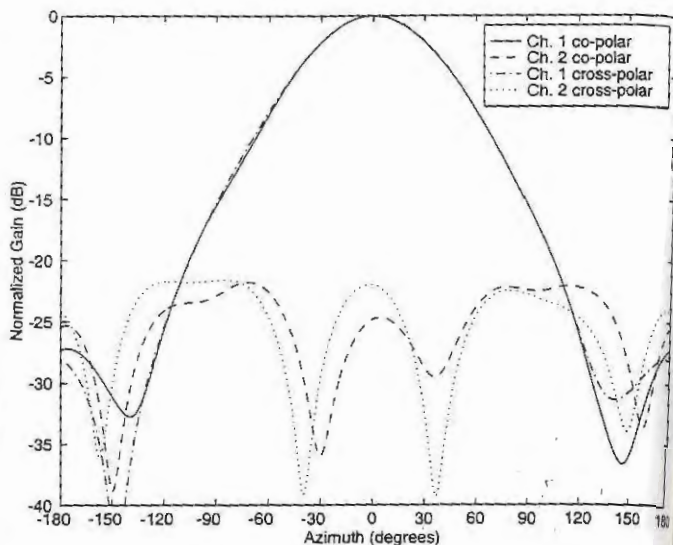


Fig. 8. Radiation pattern in azimuth at 915 MHz.

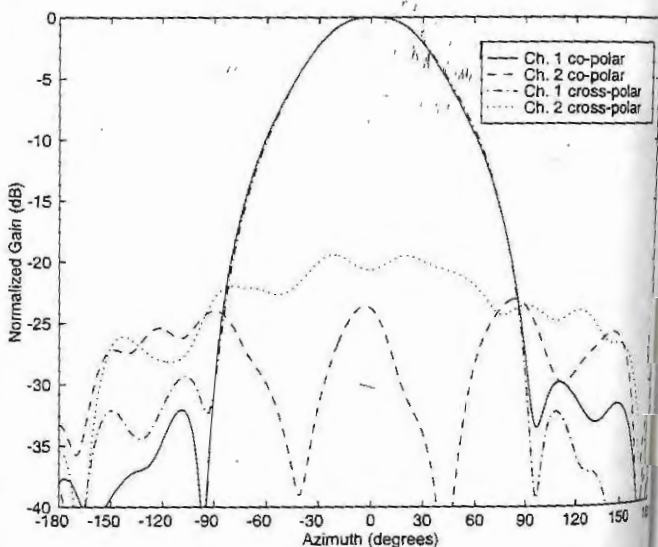
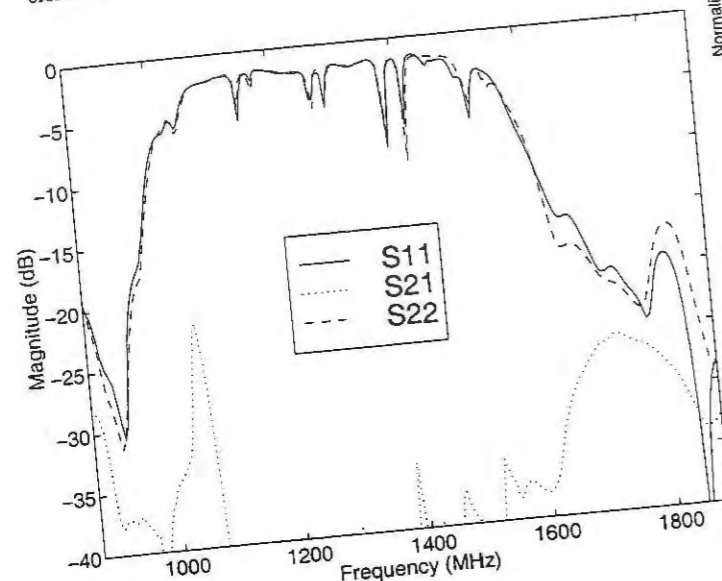
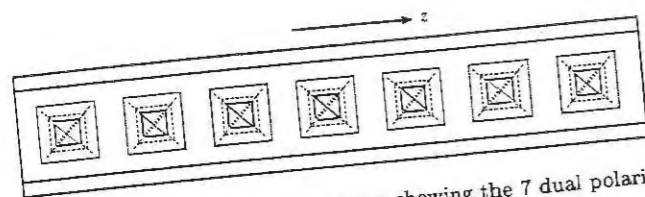


Fig. 9. Radiation pattern in azimuth at 1785 MHz.



7 such elements arranged in a linear array. There is no displacement of the elements from the centerline which allows for symmetrical radiation patterns, low cross-polarization, and good tracking between the two channels. Fig. 6 shows the schematic of the antenna. The dimensions are 1200 x 300 x 110 mm. The elements consists of three stacked patches with cross-shaped aperture in the groundplane and in the middle patch.

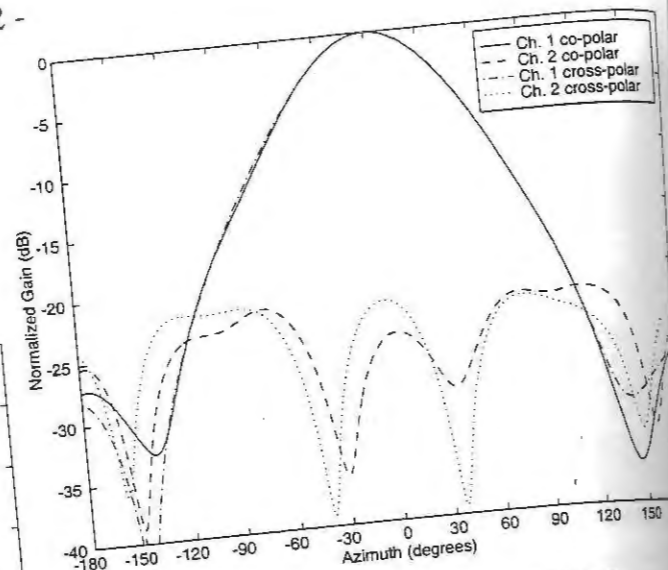


Fig. 8. Radiation pattern in azimuth at 915 MHz.

channels. This coupling is defined for the electrical far-fields of channels a and b as:

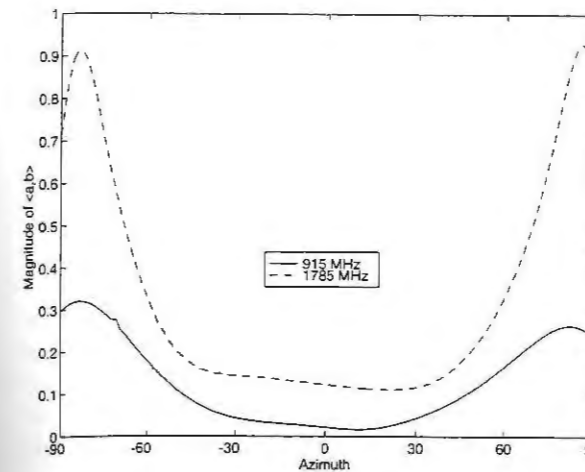


Fig. 10. Far-field coupling $\langle \mathbf{E}_a, \mathbf{E}_b \rangle / (|\mathbf{E}_a||\mathbf{E}_b|)$ in azimuth at 915 MHz and 1785 MHz.

- 73 -

Fig. 11. Radiation pattern in elevation for channel 1 at 915 MHz and 1785 MHz.

factor to the large difference between the two frequency bands could be the heavy foliage present in the area at the time of the measurements (June). The presence of foliage could also be a cause of the overall very rapidly increasing path loss with distance: 48 dB/dec at 900 MHz and 55 dB/dec at 1800 MHz. We must emphasize that this is a conclusion based on measurements in one area only, and we feel that measurements in more locations are needed.

In the investigated area the difference in coverage at 900 MHz and 1800 MHz is substantial. If we consider an output power of +40 dBm and demand -80 dBm average power at the mobile, then the -120 dB level in Fig. 5 predicts a coverage radius of 3250 m at 900 MHz but only 1550 m at 1800 MHz. However, if the 1800 MHz channels are intended for general capacity improvement only, this difference may be of small importance. In this case traffic within 1550 m may be moved to 1800 MHz channels and the 900 MHz channels are left with the traffic at larger range.

Considering possible sources of error in this study, it is still safe to conclude that the coverage at 1800 MHz is less than at 900 MHz. For sub-urban areas, we therefore propose to maximize the antenna gain at 1800 MHz, i.e. to use the whole antenna aperture in both bands. We have presented such a dual polarized dual band antenna for the GSM-900 and DCS-1800 frequency bands. It is a base station sector antenna and the horizontal beamwidths at 915 MHz and 1785 MHz are 71.5° and 69° respectively. The port-to-port isolation is greater than 26 dB in both bands.

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IV. DISCUSSION AND CONCLUSIONS

Our investigation of the propagation characteristics in a sub-urban cell indicates that the path loss at 1800 MHz could be 10-15 dB higher than at 900 MHz. A contributing

- 74 -

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